Integrated population model of Antipodean albatross for simulating management scenarios

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Introduction

Antipodean albatross

- Nationally Critical (NZ) / Endangered (IUCN)
- Breeds almost exclusively on Antipodes Island
- Biennial breeding

Threats

- Incidental captures in SLL fisheries
- Climate change
- Mice (before 2016)

Objectives

1. Fit a demographic model to field data collected since 1994
2. Develop an online simulation tool to assess relative demographic impact of management scenarios, from the model estimates

Population model

- Bayesian multi-state capture-recapture model
  - annual-based
  - inference of individual states when birds are not seen
  - year-to-year transitions between individual states
  - explicit observation process
- Model structure decided from raw data exploration and expert input (G. Elliott)

Population model - Observed states

Eight observed individual states considered, directly derived from field data:

- adult breeding inside the study area
- adult non-breeding inside the study area
- adult outside the study area (breeding or not)
- pre-breeder inside the study area
- pre-breeder outside the study area
- juvenile
- dead
- not seen

Juvenile: from fledging to first return to the island

Pre-breeder: from first return to first breeding

Population model - Latent states

Latent individual states are not observed directly:

- adult breeding inside the study area
- adult breeding outside the study area
- adult non-breeding inside the study area
- adult non-breeding outside the study area
- pre-breeder inside the study area
- pre-breeder outside the study area
- juvenile
- dead

Latent states are related to observed states via an explicit observation process

Model features and assumptions (1/2)

- Adult annual survival is sex-specific, and vary between years
- Constant and sex-independent survival rate for juveniles and pre-breeders
- Successful breeders do not breed again the following year
- Breeding probability estimated separately for adults that were previously unsuccessful and for adults that were previously non-breeding, constant over time
- Breeding success vary between years
- Transitions from juvenile to pre-breeder, and from pre-breeder to adult, depend on age, but not on year
- All juveniles become pre-breeders at 9 years old
- Movements in an out the study area are represented

Model features and assumptions (2/2)

- Mean detection probability estimated separately for:
  - breeding adults inside the study area
  - non-breeding adults inside the study area that previously bred successfully
  - other non-breeding adults inside the study area
  - pre-breeders inside the study area
  - adults and pre-breeders outside the study area
  - juveniles
  - dead individuals
- Same inter-annual variability of detection probability applied to all groups (likely to reflect timing and effort of surveys), except juveniles and dead individuals (constant)

Model fitting

- Model written in the Stan language and fitted from R
- Capture-recapture data on 3,176 individuals between 1994 and 2021
- Model code provided in report
- 6,000 MCMC samples obtained for each parameter

Results - Adult survival

Lower adult survival after 2005, especially for females

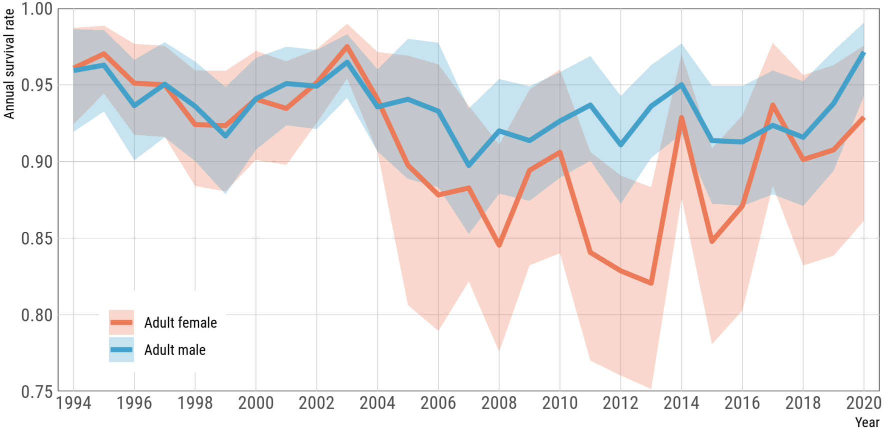


Figure 1: Annual adult survival by sex, as estimated by the model

Results - Detection probability

Lower detection probability after 2006 (no survey was done in 2006)

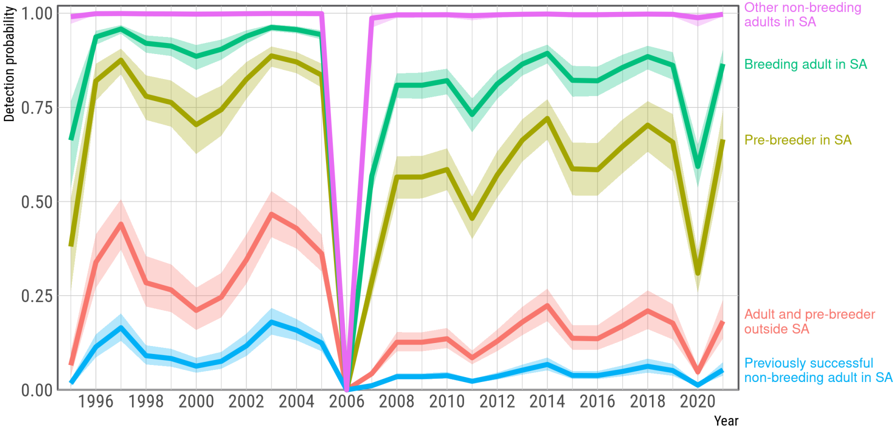


Figure 2: Detection probability by year, as estimated by the model

Results - Detection probability

Inter-annual variations in detectability was related to timing and length of surveys

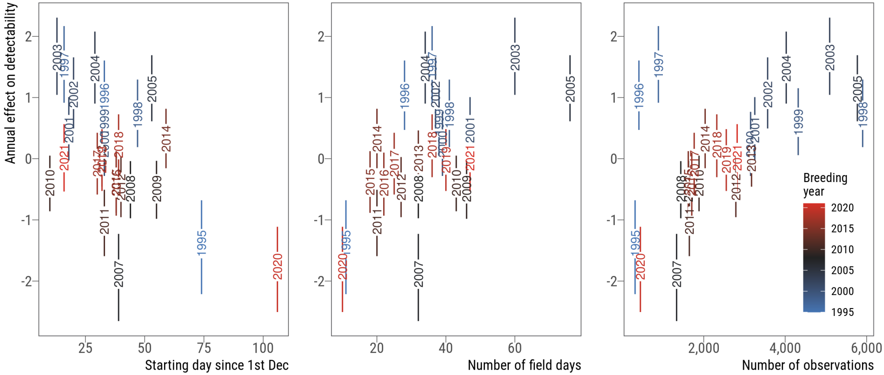


Figure 3: Relation between the year effect on detectability and the timing and length of field surveys

Results - Breeding success

Lower breeding success after 2006

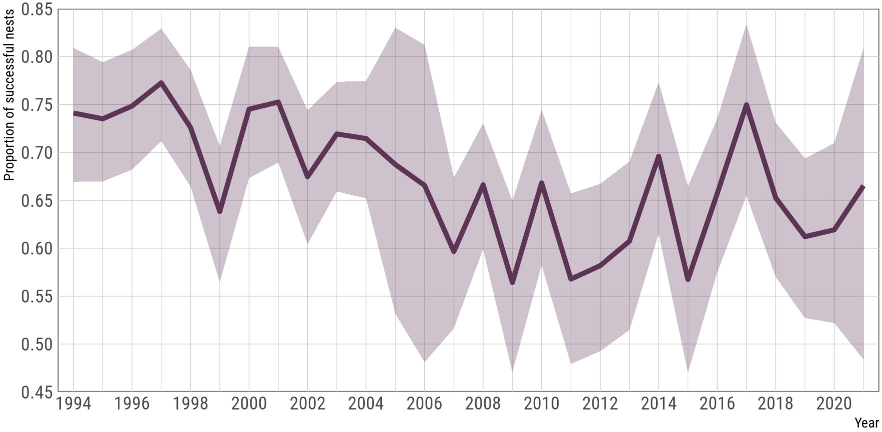


Figure 4: Breeding success by year, as estimated by the model

Results - Age transitions

Some birds never breed so never become adults in the model

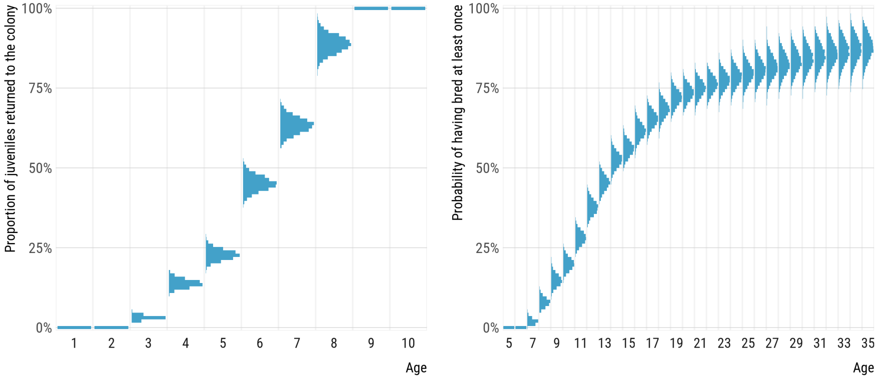


Figure 5: Cummulative probability of first return and first breeding by age

Movements in/out the study area

Females are less philopatric than males, as they are more than twice likely to leave the study area, and less likely to come back to it.

Parameter	Mean (95% c.i.)
P(leaving study area) - female	0.090 (0.081 – 0.100)
P(leaving study area) - male	0.040 (0.035 – 0.046)
P(return to study area) - female	0.177 (0.152 – 0.203)
P(return to study area) - male	0.254 (0.219 – 0.291)

Results - Other parameters

Parameter	Mean (95% c.i.)
P(breeding) - previously unsuccessful breeder	0.705 (0.686 – 0.723)
P(breeding) - previously non-breeder	0.641 (0.628 – 0.654)
Annual survival - pre-breeder	0.922 (0.913 – 0.931)
Annual survival - juvenile	0.879 (0.869 – 0.888)
P(detection) - juvenile	0.0002 (0.0000 – 0.0007)
P(detection) - dead individual	0.0008 (0.0005 – 0.0012)

Simulations

Simulations of the future of the population, using the demographic parameters estimated in the model

- Only the population within the study area is simulated
- Total population size calculated from scaling up the study area population, based on 1994–1996 surveys - multiplier of 36.58 = 1 / 2.7332% from G. Elliott & K. Walker (2020)
- Simulations over 30 years
- Time-varying parameters were sampled from the period post-2008

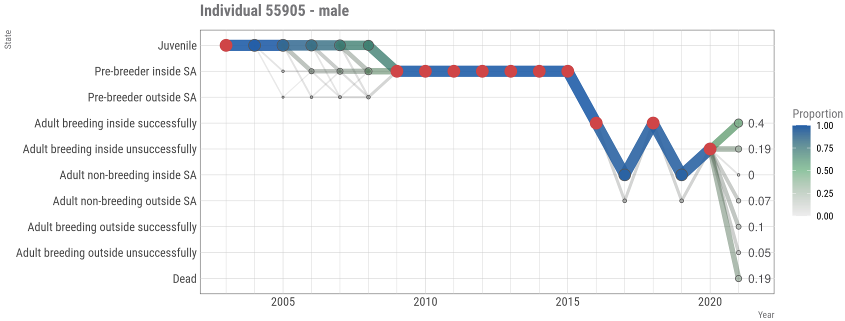
Simulations - Initial population

The population structure in 2021 inside the study area is used to initialise the simulations.

The latent state of individuals was simulated for the whole 1994–2021 period to get the structure of the population in 2021.

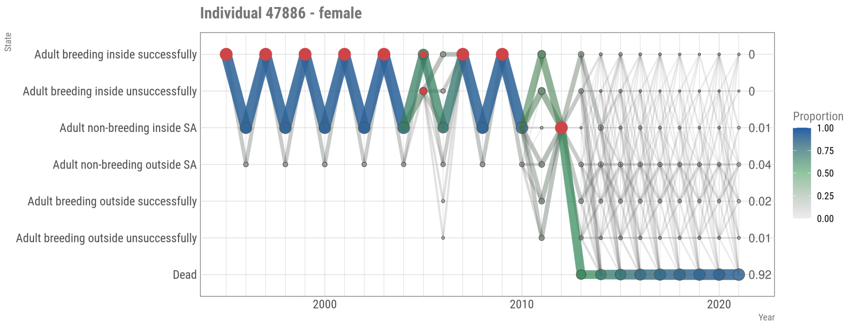
Simulations - Initial population

Example of a simulation of latent states for an individual, from known states (red dots) and from the transition probabilities estimated in the model



Simulations - Initial population

Another example of a simulation of latent states for an individual, from known states (red dots) and from the transition probabilities estimated in the model



Simulations - Initial population results

The annual number of breeding pairs was calculated from the minimum number of breeding females or breeding males.
The simulated population size is slightly higher than ground counts because it includes individuals that may be undetected.

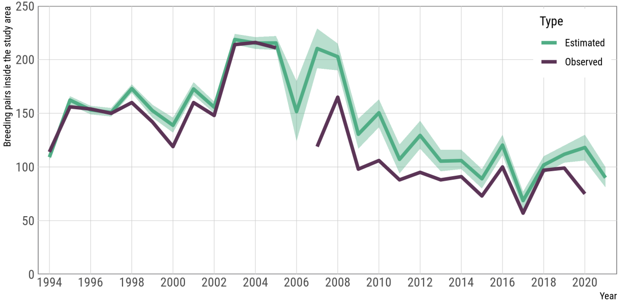


Figure 6: Comparison of the annual number of breeding pairs obtained from the model and from ground counts

Simulations - Current context

Based on the demographic parameters for the period 2008–2021, a significant population decline is predicted:

- Annual decline of 4.84%
- From 90 pairs in 2021 to 11 pairs after 30 years (inside the study area)
- This represents a 87.7% population reduction over 30 years

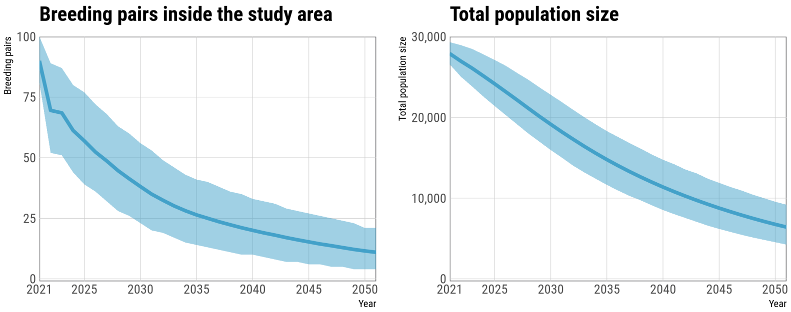


Figure 7: Simulation of the population over the next 30 years

Online simulation tool

Scenarios can be simulated by specifying the impact of threats on specific demographic parameters (survival and productivity rates)

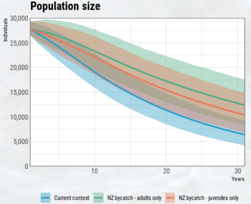
- The impact of threats can be added or removed from the current context
- The impact may be specified in parameter units, or as a number of individuals
- Threat impacts are assumed to be proportional to population size

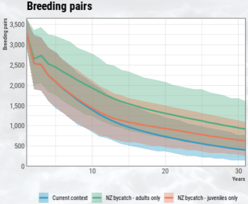
Online simulation tool - Parameters

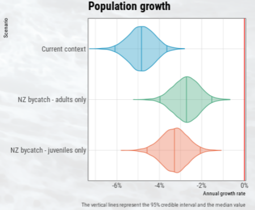
Online simulation tool - Results

Simulation results

☐ Study area ☑ Whole island







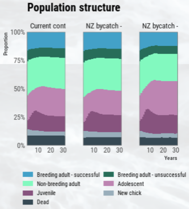
	Population after 30 years
Current context	6,412 birds (95% c.i.: 4,244 to 9,183)
NZ bycatch - adults only	12,370 birds (95% c.i.: 8,305 to 17,563)
NZ bycatch - juveniles only	10,397 birds (95% c.i.: 6,842 to 14,891)

	Breeding pairs after 30 years
Current context	401 breeding pairs (95% c.i.: 146 to 768)
NZ bycatch - adults only	920 breeding pairs (95% c.i.: 402 to 1,610)
NZ bycatch - juveniles only	627 breeding pairs (95% c.i.: 256 to 1,098)

	Annual growth rate
Current context	-4.84% (95% c.i.: -6.07% to -3.65%)
NZ bycatch - adults only	-2.73% (95% c.i.: -3.96% to -1.54%)
NZ bycatch - juveniles only	-3.30% (95% c.i.: -4.56% to -2.08%)

Summary of demographic parameters

Parameter	Scenario	Value
Annual survival - juvenile	Current context	87.93% (95% c.i.: 86.95% to 88.83%)
	NZ bycatch - adults only	87.93% (95% c.i.: 86.95% to 88.83%)
	NZ bycatch - juveniles only	96.39% (95% c.i.: 95.41% to 97.30%)
Annual survival - adolescent	Current context	92.20% (95% c.i.: 91.30% to 93.12%)
	NZ bycatch - adults only	92.20% (95% c.i.: 91.30% to 93.12%)
	NZ bycatch - juveniles only	92.20% (95% c.i.: 91.30% to 93.12%)
Annual survival - adult female (all years)	Current context	88.14% (95% c.i.: 78.09% to 96.46%)
	NZ bycatch - adults only	91.96% (95% c.i.: 81.94% to 100.00%)
	NZ bycatch - juveniles only	88.14% (95% c.i.: 78.09% to 96.46%)
Annual survival - adult male (all years)	Current context	92.84% (95% c.i.: 87.95% to 97.90%)
	NZ bycatch - adults only	95.10% (95% c.i.: 90.23% to 100.00%)
	NZ bycatch - juveniles only	92.84% (95% c.i.: 87.95% to 97.90%)
P(breed) - adults previously breeding unsuccessfully	Current context	70.50% (95% c.i.: 68.62% to 72.33%)
	NZ bycatch - adults only	70.50% (95% c.i.: 68.62% to 72.33%)
	NZ bycatch - juveniles only	70.50% (95% c.i.: 68.62% to 72.33%)



Population structure

	Current context	NZ bycatch - adults only	NZ bycatch - juveniles only
Breeding adult - successful	14.3%	14.8%	12.1%
Breeding adult - unsuccessful	8.4%	8.6%	7.1%
Non-breeding adult	27.5%	28.3%	23.9%
Adolescent	24.2%	21.4%	29.9%
Juvenile	13.5%	15.2%	16.5%
New chick	3.6%	4.4%	3.6%
Dead	8.5%	7.3%	6.9%

Next steps

- Refinements to the model?
- Simplification of the simulation tool before making it publicly available online
- Finalisation of report

Discussion - Conclusions

- Concerning decline in survival and productivity, supported by population projections
- Similar results to previous studies (e.g. Edwards et al. 2017)
- Potential recovery of adult survival rates in the last few years
- Despite the inclusion of movements outside the study area in the model, permanent emigration may still result in an underestimation of survival rates
- The online simulation may help prioritising management strategies to optimise the recovery of the population
- Feedback welcome

Acknowledgements

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